Surf Zone Mine Vulnerability

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LONG-TERM GOAL

The long-term goals of the mine vulnerability task are to: (1) Identify key damage mechanisms leading to the development of kill criteria for explosive neutralization of a variety of anti-tank, and anti-personnel Surf Zone (SZ) threat mines, (2) develop and exercise a methodology for assessing the vulnerability of SZ mines to explosive mine neutralizations, (3) assess the effectiveness of various types of mine neutralization systems against SZ mines, and (4) develop physics-based predictive capabilities for assessing system effectiveness against threat mines in a tactical SZ environment.

OBJECTIVES

The Navy is currently developing a number of explosive neutralization systems, designed for large area SZ mine clearance. In support of these efforts, the objectives of this task are: (1) to characterize the vulnerability of SZ threat mines to explosive neutralization by establishing critical loading levels for neutralizing the mines, (2) to estimate the effectiveness of explosive neutralization systems in countering SZ threat mines, and (3) to develop from this a general methodology.

APPROACH

The technical approach is to employ a combination of laboratory testing, analysis, simulation and field testing to fully assess, for each threat mine studied, its vulnerabilities to explosive neutralization. The mine(s) are studied through non-destructive physical analyses, static and dynamic function tests, material property tests, and ultimately exposure to dynamic explosive loading in a free-water, precision test environment. During dynamic loading studies, subject mines and fuzes are instrumented in order to

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Surf Zone Mine Vulnerability**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center,Indian Head Division,Code 4210,Indian Head,MD,20640**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

time resolve the response of the target with the explosive event (e.g., shock, bubble, flow, etc.). The testing is supplemented by analyses in which advanced computer modeling simulates the interaction of both the mine target and the explosive system output, using a coupled Eulerian-Lagrangian hydrodynamic code. Laboratory and field-testing conducted during and following the analysis provides additional insight into kill/damage mechanisms and provides verification of the computer modeling predictions. Target response data, combined with explosive neutralization system lethality data in a simulated SZ environment, is being utilized to develop a non-deterministic predictive tool to assess DET and SABRE system performance in a SZ environment.

WORK COMPLETED

Conducted the mine vulnerability study of the target L influence type mine with three different fuze configurations (two magnetic sensors, one mechanical tilt-rod). This was the first time that an influence type mine was investigated. The study included:

- DYSMAS analysis of explosive loading and fuze/mine case structural response
- Material properties characterization
- Detonator characterization
- Explosive fill composition characterization
- Phenomenology testing of instrumented inert fuzes for various explosive loading configurations
- Sympathetic detonation testing of explosive loaded mine cases
- Identification of primary kill mechanisms for 3 different fuze types
- Development of post-test threat assessment for 3 fuze configurations

Conducted a series of laboratory type sympathetic detonation tests against the target E tilt-rod mine to more fully investigate this damage mechanism.

The FY98 program culminated in a 6.4 funded lethality field testing of DET and SABRE systems against live and inert target L and target E mines.

RESULTS

The DYSMAS finite-element hydrocode was used to compute the dynamic response of target L from a SABRE line charge and a single line of DETCORD. Three different fuze types were analyzed; namely the two types of magnetic proximity induction fuzes and an electromechanical proximity fuze.

The DYSMAS hydrocode allowed us to compute the shock pressure and impulse caused by the SABRE line charge as a function of standoff from the mine, water depth, and sea bottom characteristics. The pressure and impulse calculations were found to be very sensitive to the sea bottom; especially the air content. The DYSMAS results were in good agreement with test values for a reasonable estimate of air content in the sand. The structural response calculations capitalizing on DYSMAS capability to consider fluid-structure interaction showed that the fuze body of the magnetic fuzes experiences very high vertical and transverse accelerations. A finite-element of a typical circuit board indicated amplification of these accelerations indicating the potential for failure of vital electronic components. This failure mechanism was verified in the phenomenology tests conducted at SRI. The mechanical properties of the material in the mine case were measured at -40^{o}F, 77^{o}F and 140^{o}F to aid in analysis of

the mine case. The analysis showed that the mine case body of the magnetic fuzes experiences very large rotational deformation and stresses indicative of a potential failure mode.

The dynamic response analysis of the electromechanical fuze configuration showed that the mine was most vulnerable to bubble flow from SABRE vice shock wave pressure and impulse. The response was very similar to a similar mine which was tested at the Eglin Air Force Base test pond and was found to be vulnerable to bubble flow.

Similar analyses were made for a single DETCORD in close proximity to the fuze body of the three types of mines. The analyses also showed that the fuze electronics are vulnerable to the high vertical and transverse accelerations, which were confirmed by tests. A finite-element analysis of the thin wall case of the fuze body indicated very large radial deformations, which suggested failure of the seals and flooding as a potential failure mechanism.

Analytic models were developed for the three fuze types to aid in identifying mine vulnerabilities, and to provide physics models for statistical analyses of mine test data. The analytic models for the magnetic fuzed mines were developed by simplifying the system into a single degree of freedom system (SDOF) considering the fuze body as a rigid mass connected to a linear spring simulating the rotational deflection of the mine case. The primary loading was the lateral shock impulse on the fuze body, which was deduced from the DYSMAS analyses. The models were programmed in a MATHCAD model, which will be used in the statistical analysis of test data to determine kill probability as a function of standoff of SABRE from the mine.

The target L mine vulnerability study was instrumental in identifying functional and structural fuze damage mechanisms. The phenomenology testing identified failure modes to relative to fuze electronic components, sterilization features, structural weaknesses, water seals and premature actuation of the detonator. The detailed test results are classified and will be provided in an upcoming report. Every failure mode that was identified during the phenomenology tests series was later confirmed during the field tests at Eglin AFB. The phenomenology tests, conducted at the SRI test pool in Tracy California, dynamically loaded tactical inert Target L mines and fuzes using lengths of 417 grain per foot detonating cord at various standoffs from the mine. The results of very close-in shots (6-12 inch standoff from the fuze) were consistently to neutralize the target by shearing the fuze off of its base, which remained affixed in the mine case. For shots at distances of 30 to 60 inches, several damage mechanisms were observed including:

- “Forced” firing of the detonator due to high G-loading of the circuit boards which, in turn, caused a mechanical relay to function, dumping voltage to fire the detonator.
- Fracture and subsequent flooding of the fuze water seals (bellows), which in turn caused batteries and other electronic equipment to short out, rendering the fuze non-functional.
- Functioning of the sterilization feature, by compressing a slider mechanism that in turn activates the sterilization feature; once activated, the fuze is powered down and the detonator is blocked from firing into the lead.
- Damage to the power switch causing the fuze to power down, thus becoming a non-threat.

At standoffs in excess of 60 inches, similar failure/damage modes were exhibited, but to a lesser extent as the magnitude of the loading decreased with standoff.

Sympathetic detonation testing conducted against target L explosive loaded mines demonstrated that this mine is not vulnerable to sympathetic detonation or reaction. This is thought to be due to the plastic mine case material which does not lend itself to confinement of the explosive fill.

The target E sympathetic detonation test results demonstrated that the main charge is vulnerable to sympathetic reaction, but not necessarily a high order detonation. A series of tests were conducted in which various lengths of 417 grain per foot detonating cord were place against explosive loaded target E mine cases, that were immersed underwater in a 50 gallon drum. The results showed a close correlation between the length of detonating cord in contact with the mine and the extent to which the mine reacted sympathetically. The results indicated the minimum amount of detonating cord contact required to cause a sympathetic reaction sufficient to kill the mine. With lesser degrees of contact, the mine case was damaged and small portions of the explosive fill may have crumbled or deflagrated, but the damage was insufficient to consider the mine neutralized.

As noted earlier, with respect to target L, the field test results were consistent with the phenomenology and sympathetic detonation test results. For target E, while the majority of the live mines tested exhibited a low order sympathetic reaction, only 3 out of 12 (6 of which were back-filled with U.S. explosives after having been inerted) were sufficiently damaged to render them a no-threat. Although it was desired to defeat the target E mines, the explosive test configurations were chosen to vary the cord placement rather than to ensure a kill. Additionally, field test limitations did not permit a high degree of control over the detonating cord contact area, as was achieved during the 6.2 sympathetic reaction studies. The field test results reiterated the dependency on intimate contact between the detonating cord and the mine case, when attempting to achieve sympathetic reaction as a kill mechanism. The test results again point to the importance of understanding the extent of interaction, prior to detonation, between certain types of distributed explosive and target E mines.

IMPACT/APPLICATION

The 6.2 study of the target L mines provided invaluable data for the 6.4 community in field test planning and in assessing the post-test status of mines and fuzes insofar as whether or not they posed a threat. Because the Target L fuzes were electronic and detonators were removed, there was no obvious visual indication that the fuze actuated if this happened to be the failure mode. Data gathered during the 6.2 phenomenology and detonator characterization studies enabled an inert “tell-tale” to replace the detonator and thus provide a means of determining whether or not the fuze functioned. The 6.2 results also provided guidelines for mine spacing and expected kill distances.

As previously noted, this year’s effort was the first in which influence fuzes containing electronic components were tested. The results provide an important look at the relative hardness in general of these fuze/mine types compared with non-influence and/or purely mechanical mines previously tested.

The DYSMAS analyses represent another major step in developing physics based predictive capabilities for assessing the effectiveness of explosive systems against the multitude of threat mines in amphibious assault scenarios.

TRANSITIONS

The phenomenology and sympathetic detonation test results along with the analyses were employed to develop pre-test predictions and aid in mine placement configurations for the 6.4 system lethality tests. Important information and data on fuze damage mechanisms and the associated threat status were provided to the 6.4 community to support the lethality test effort. A copy of the final 6.2 report will be provided to 6.4 community and MCM community at large to disseminate the valuable information regarding the new vulnerability data.

RELATED PROJECTS

1. PMS 407 is developing distributed explosives systems and is planning P3I programs to for Surf Zone MCM.

2. The sand modeling task is developing approaches to model the bottom in different environments. The interplay of the bottom effects the peak shock pressures and in many cases the target vulnerability.

PUBLICATIONS

McDonald, W.W. and Goeller, J.E., 1997: “Determination of Pressure Plate Mine Vulnerability to Line Charge Clearance Systems,” IHTR 2060, 31 Dec, CONFIDENTIAL.